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APPLICATION FOR LETTERS PATENT
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TITLE OF INVENTION:

Gamma Camera Using Rotating Scintillation Bar Detector
And Method For Tomographic Imaging Using The Same

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TO WHOM IT MAY CONCERN, THE FOLLOWING IS
A SPECIFICATION OF THE AFORESAID INVENTION

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GAMMA CAMERA USING ROTATING SCINTILLATION BAR DETECTOR AND METHOD FOR TOMOGRAPHIC IMAGING USING THE SAME

BACKGROUND OF THE INVENTION

1. Field Of The Invention

The present invention generally relates to nuclear medicine, and systems for obtaining nuclear medicine images of a patient's body organs of interest. In particular, the present invention relates to a novel detector configuration for nuclear medical imaging systems that are capable of performing single photon emission computed tomography (SPECT) to obtain tomographic images.

2. Description Of The Background Art

Nuclear medicine is a unique medical specialty wherein radiation is used to acquire images that show the function and anatomy of organs, bones or tissues of the body. Radiopharmaceuticals are introduced into the body, either by injection or ingestion, and are attracted to specific organs, bones or tissues of interest. Such radiopharmaceuticals produce gamma photon emissions that emanate from the body. One or more detectors are used to detect the emitted gamma photons, and the information collected from the detector(s) is processed to calculate the position of origin of the emitted photon from the source (i.e., the body organ or tissue under study). The accumulation of a large number of emitted gamma positions allows an image of the organ or tissue under study to be displayed.

Single photon imaging, also known as planar or SPECT imaging, relies on the use of a collimator placed in front of a scintillation crystal or solid state detector, to allow only gamma rays aligned with the holes of the collimator to pass through to the detector, thus inferring the line on which the gamma emission is assumed to have occurred. Conventional single photon imaging techniques require gamma ray detectors that calculate and store both the two-dimensional position of the detected gamma ray (in x, y coordinate form) and its energy (typically in keV).

Present day single photon imaging systems all use large area scintillation detectors (on the order of 2000 cm^2). Such detectors are made either of sodium iodide crystals doped with thallium (NaI(Tl)), or cesium iodide (CsI). Scintillations within the NaI crystal caused by absorption of a gamma photon within the crystal, result in the emission of a number of light photons from the crystal. The scintillations are detected by an array of photomultiplier tubes (PMTs) in close optical coupling to the crystal surface. Energy information is obtained by summing the signals from the PMTs that detected scintillation photons, and position information is obtained by applying a positioning algorithm to the quantitative signals produced by the PMT array. The original gamma-ray camera is described in U.S. Patent No. 3,011,057 issued to Hal Anger in 1961.

Because the conventional Anger camera uses a thin planar sheet or disk of scintillation crystal material, it is necessary to cover the entire field of view of the crystal with light detectors such as PMTs or photodiodes. PMTs do not contribute to high spatial resolution because of the uncertainty in PMT output signals as a function of scintillation event position, the signal from a PMT as a function of position being a bell-shaped curve having a slope that introduces uncertainty as to the position of the scintillation event that produced it. Complex position calculating electronics thus are usually required to be used with PMT detectors.

Additionally, the sampling capability of such scintillation crystals could be improved by increasing the number of gamma photons absorbed by the crystal that emanate from an imaging object, and consequently increasing the number of scintillation events that can be detected for use in constructing an image.

The CsI camera is typically used with either a single silicon-based photodiode detector or an array of silicon-based photodiode detectors, which detect scintillation events emitted from the CsI crystal. CsI crystals are used where the relatively low cost, ruggedness and spectral response of the CsI crystal are desired in favor of alternative crystal materials such as NaI. The

conventional CsI camera still requires complex position calculation electronics.

The bar detector is a specific configuration of scintillation detector that has been used in astronomical and high energy physics applications. The bar detector consists of an elongated scintillation crystal bar having a relatively small cross section. A photosensor such as a PMT is optically coupled to each end of the bar. The light from a gamma photon event within the scintillation crystal volume is detected by the two PMTs. The timing or signal information can be used to determine the location of the event in the bar. Additional bars can be placed next to each other for two dimensional detection.

A so-called rotating slit gamma camera is also known in the art, see, e.g., U.S. Patent No. 4,514,632 to Barrett, issued April 30, 1985. The rotating slit camera has an elongated slit provided in an opaque disk located between the imaging object and the detector, such that scintillation event detection is obtained only in one dimension along the length of the slit (i.e., only a single spatial coordinate is obtained) at a time. The disk is rotated with respect to the detector to obtain spatial position information along other directions. One advantage of the rotating slit camera is that it eliminates the requirement for the inefficient simple collimator or pinhole apertures in the conventional Anger camera, which greatly restrict the percentage of gamma photons emanating from an imaging object that ultimately reach the detector.

There is thus an existing need in the art to provide a new type of tomographic camera that eliminates the need for expensive and complex position calculating electronics, while providing high position resolution at low or high gamma energies and improving reliability over conventional PMT-based cameras, and decreasing cost.

SUMMARY OF THE INVENTION

The present invention solves the existing need by providing a gamma camera having a scintillation detector formed of a stack of scintillation bar

detectors with slat collimation. Scintillation photons are detected from the ends of the bars by a pair of light-sensitive detectors.

According to one aspect of the invention, a gamma camera includes a number of bar detector strips made of scintillating material, arranged in a stack configuration, where at least one photodetector is coupled to each end of the stack, and a slat collimator including a plurality of elongated slats, for collimating each of the bar detector strips to receive gamma photons in only a single dimension.

According to another aspect of the invention, a method of obtaining tomographic images of an object includes the steps of obtaining a number of sets of planar integral scintillation event data from the object at a number of azimuth angles of a rotating scintillation detector for each of a number of gantry angles of a gamma camera, and reconstructing the sets of planar integral scintillation event data to form a tomographic image of the object.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will become more clearly understood from the following detailed description in connection with the accompanying drawings, in which:

FIG. 1 is an isometric view of a rotating bar detector gamma camera, according to the present invention;

FIG.2 is an end plan view of the rotating bar detector gamma camera of FIG. 1;

FIG. 3 is an exploded view of one embodiment of the invention, showing the relationship between the bar detector strips and the slat collimators; and

FIG. 4 is a diagram illustrating the use of the rotating bar detector camera according to the invention, to obtain tomographic images of a subject.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, according to one preferred embodiment of the invention, a gamma camera detector 100 is provided, which is constructed of a stack of scintillation bars 101. In the preferred embodiment, each

scintillation bar 101 is a narrow strip of CsI, however other scintillator materials can be used, such as NaI, LSO, LaBr3, LaCl3, etc.

Each bar 101 is collimated by a "slat" collimator 103, which collimates gamma photons in one dimension only (i.e., along the length of the bar), similar to the rotating slit camera as disclosed in the abovementioned '632 patent. Unlike the present invention, however, the '632 patent utilizes a conventional thin planar sheet of scintillation crystal material.

Light photons generated by absorption of gamma rays within the bars 101 are collected at the ends of each bar by a pair of photodetectors 201, 202. In the preferred embodiment, silicon strip detectors (SSDs) are used as the light photon detectors 201, 202; other types of photodetectors also may be used in accordance with the invention, such as small area photodiodes or photodiode arrays, position-sensitive PMTs (PS-PMTs), or other solid-state photodetectors.

As shown in Fig. 1, the detector 100 is composed of a stack of narrow bar detector strips, each having the same length **L**, width **w**, and depth **d**. As illustrated, the width dimension **w** is significantly smaller than the depth **d**. The bar strips are each collimated by slat collimators 103. As shown in Fig. 3, the slat 103 length and spacing matches the length and width of the bars 101. The individual bars 101 may be located between slats 103, or the entire slat collimator may be placed in front of the bar detector stack with respect to an imaging object. The preferred dimensional proportions of the bars 101 are not shown in Fig. 3 for simplicity.

When placed adjacent to an imaging object that is emitting gamma radiation, each collimated bar will absorb gamma photons from a plane within the object. Gamma absorptions within each narrow strip produce a number of light photons that travel along the length of the bar strip in each direction, and are collected at the ends of the bar strip by the pair of SSDs 201, 202. As explained above, because the slat collimators collimate gamma photons in only one dimension (along their length), high position resolution is required in only the dimension perpendicular to the collimated bars. Consequently, a

desirable value for the width **w** of the bar detector strips for contemplated medical imaging applications is on the order of 3 mm.

Because the slat collimators collimate gamma photons in only one dimension, the stack of bar detectors collects a set of planar integrals at each rotational position, as opposed to the line integrals that are collected by the conventional PMT arrays of the conventional Anger gamma camera. Thus, after collecting an adequate number of planar events at a fixed gantry angle, the bar detector stack 100 is rotated azimuthally about its central normal axis 203 as shown in Fig. 2. The amount of rotation can be 90 degrees, or may be a different amount. The bar detectors then collect another set of planar events at the rotated angle. As shown in Fig. 4, the process is repeated at a number of different gantry angles 401, 403, 405, and 407 with respect to an imaging object 402 such as a patient undergoing medical imaging. The resulting sets of planar integrals can be reconstructed to form a full tomographic image of the object 402.

Use of the stack of bar detector strips 100 in a rotating slat collimator configuration exhibits several desirable characteristics. As explained above, because of the one-dimensional nature of the detection, high positional resolution is required only in the dimension perpendicular to the slat collimators, and thus a narrow width bar detector strip on the order of 3 mm may be used, with light photon collection at each end. Because light produced by scintillation events in each bar is channeled within the small area of each bar, extremely high count rates are possible without pileup from spatially separated events, especially if each bar detector is provided with its own detector readout electronics (in the case of PS-PMTs, each PS-PMT would detect light from multiple bars, with a corresponding reduction in the maximum count rate).

The reduction in pileup in turn allows the use of slower scintillator materials, such as CsI, which are well-matched to compact photodetectors such as photodiodes and SSDs. Further, while the spatial resolution along the length of the bar detectors is limited by the light collection ratios between

the pair of photodetectors 201, 202 at each end, it is still good enough to perform energy correction ("Z map") to improve system energy resolution.

The use of SSDs as photodetectors coupled to CsI bar detector strips is of particular interest, in that SSDs may be grown to match the cross-section of the bars (either as single photodetectors or as arrays), and SSDs are very low noise devices. Each pair of SSDs collects the total light produced by each gamma event, thus providing a large signal-to-noise ratio. However, as mentioned above, arrays of smaller area photodiodes coupled to the bar detectors, or position-sensitive PMTs, are other possibilities for implementation of the photodetectors.

Because the depth of the bar detector does not affect spatial resolution, high spatial resolution is possible at high energies, and the septa (slat collimators) can be made thick without causing septal artifacts in the resulting images.

The rotating bar detector gamma camera according to the present invention provides a number of advantages in the art, including: relatively low overall cost; elimination of drift-prone PMTs and associated complex position calculation electronics; use of reliable solid-state silicon detectors; complete elimination of the need for positioning electronics, or alternatively use of very simple position readout electronics; a compact, flat detector profile, and high position resolution at all energy levels.

The invention having been described, it will be apparent to those skilled in the art that the same may be varied in many ways without departing from the spirit and scope of the invention. Any and all such modifications are intended to be included within the scope of the following claims.